

APPENDIX M

SURFACE GEOLOGY

Ktm TWO MEDICINE FORMATION (UPPER CRETACEOUS)

Sedimentary facies - Nonmarine mudstones with some sandstone, north of Augusta. Upper and middle parts consist mostly of gray-green to gray mudstone with reddish-gray, red-brown, and purple interbeds. Interbeds of fine to medium grained sandstone in upper part of sandstone beds. Locally contain abundant vertebrate bones and pelecypods in upper 150 meter (m). Thin conglomerate about 245 m below the top occurs north of Birch Creek (Cobban, 1955). Contains many thick beds of gray to greenish-gray sandstone, interbedded with gray-green, olive-drab, and gray mudstone in lower part of formation (about 170 m). Locally as much as 50 m thick, poorly indurated, fine to medium-grained, massive to thin-bedded, and in part crossbedded sandstone beds, a conglomerate is included in the sandstone (Mudge, 1972). Carbonaceous shale, as much as 1.5 m thick, widespread near base of formation. Locally abundant petrified wood in a sandstone unit above the carbonaceous shale, erodes into badland topography similar to the St. Mary River Formation. The Two Medicine is about 670 m thick. Widespread in eastern part of mapped area and present in the North Fork Sun River area.

Km MARIAS RIVER SHALE (UPPER CRETACEOUS)

Mainly dark-gray, marine mudstone, ranges from 365 to 395 m thick. Divided into four members by Cobban, Erdmann, Lemke, and Maughan (1959b, 1976), in descending order: Kevin, Ferdig, Cone, and Floweree.

The Kevin is dark-gray, calcareous mudstone with some thin, very fine grained sandstone in upper part. Characteristically contains many thin, micaceous bentonite beds and zones of calcareous and ferruginous limestone concretions. Bentonite beds thicker and far more numerous in southern outcrops. Pelecypods and ammonites common. The Kevin Member ranges from about 226 m thick in the east to as much as 326 m in the west (Mudge, 1972).

The eastern facies of the Ferdig Member contains gray, noncalcareous mudstone with many very thin, iron-stained sandstone beds, concretions of yellow-weathering limestone and red-weathering ferruginous dolostone, and some very thin bentonite beds, about 50 m thick. The western facies of the Ferdig, exposed in the North and South Forks of the Sun River, is about 150 m thick, and resembles the Cardium Formation of southern Alberta, Canada (Mudge, 1972). Contains nodular sandstone, sandy shale, and even-bedded sandstone in the middle and upper parts of the western facies; thick-bedded, light-gray sandstone in upper parts. Organic burrows and trails common. The lower part is like that exposed in the eastern facies.

The Cone Member contains abundant, very thin, medium-gray, calcareous siltstone and crystalline limestone beds in the upper part and dark-gray noncalcareous fissile shale with some limestone concretions in the lower part (Cobban, Erdmann, Lemke, and Maughan, 1976); contains several bentonite beds throughout. The upper beds commonly have petroliferous odor on a freshly broken surface. Contains a characteristic fauna which includes *Mytiloides labiatus* (Cobban, Erdmann, Lemke, and Maughan, 1976). Ranges from 15 to 30 m thick.

The Floweree Member is noncalcareous, dark-gray, nonfossiliferous shale (Cobban, Erdmann, Lemke, Maughan, 1976; Mudge, 1972). Locally contains basal siltstone with chert-pebble conglomerate. The shale has metallic luster and yellowish-brown stains on bedding and fracture planes (Mudge, 1972). Ranges from 9 to 12 m thick.

Kb BLACKLEAF FORMATION (LOWER CRETACEOUS)

Gray, marine mudstone and interbedded sandstone. Divided into three members by Cobban, Erdmann, Lemke, and Maughan (1959b, 1976), in descending order: Vaughan, Taft Hill, and Flood. The formation ranges from about 200 m thick in southern outcrop to about 490 m in the west and about 260 m in the north.

The nonmarine Vaughan Member consists of alternating gray to olive-drab mudstones and bentonitic mudstone with many thin interbeds of light-gray, locally crossbedded sandstone. Contains less sandstone to the north and lower beds are laterally equivalent to upper part of the marine Taft Hill strata to the south. Locally, beds of conglomerate fill small channels at base of some sandstone units (Mudge, 1972). In the Sun River area, the upper part of member contains tuffaceous debris, one bed contains accretionary lapilli (Mudge, 1972). Member locally contains wood and leaf fragments and, in the vicinity

of Teton Pass, contains beds of coal and carbonaceous shale. Ranges from 90 m thick in the eastern outcrops to possibly 213 m in the north.

In the south, the marine Taft Hill Member consists of thinly bedded, gray, fossiliferous sandstone, locally crossbedded and ripple marked (Mudge, 1972), interbedded with dark-gray mudstone containing some very thin bentonite beds. These units grade northward into nonmarine lithologies of the Vaughan. The Taft Hill is as much as 183 m thick in west-central part of the area, thins to 0 m to the north and 58 m in the southeast outcrop.

The marine Flood Member in the south consists of two sandstone units with a distinctive intervening shale unit. Lower sandstone absent to the north where upper sandstone unit is thicker and shale unit thinner, as compared to southern exposures. Gray, thinly crossbedded, very fine grained, finely micaceous and moderately well sorted sandstones (Mudge, 1972); commonly weather grayish brown. Locally large sandstone nodules in lower part. The shale unit, transitional with upper sandstone unit, is distinct, very dark gray fissile shale with a metallic luster on bedding surfaces. Thin sandstone lentils and nodules of limestone and claystone common, locally phosphatic nodules present. Organic trails and burrows abundant in transition zone. The Flood ranges from 45 m thick in eastern outcrops of 165 m in western. About 40 m thick in the north part of mapped area (Rice and Cobban, 1977).

Kk KOOTENAI FORMATION (LOWER CRETACEOUS)

Nonmarine, gray-green and maroon mudstone with numerous lenticular, poorly sorted, greenish-gray sandstone beds, locally crossbedded and contain lenticular basal conglomerates (Mudge and Sheppard, 1968; Mudge, 1972). Brown to brownish-gray limestone with thin to thick lenses of coquina with pelecypods and gastropods is near top of formation. Brown, iron-stained limestone nodules common in mudstone beds. The Sunburst Sandstone Member of Rice and Cobban (1977) is at base of formation in the southern outcrops and absent to the north. The Sunburst consists of many thin beds of hard, noncalcareous, poorly sorted quartz sandstone with few scattered grains of chert and feldspar. The Kootenai ranges from 198 to more than 305 m thick.

Kjm LOWER CRETACEOUS MOUNT PABLO FORMATION AND JURASSIC MORRISON FORMATION AND ELLIS GROUP, UNDIVIDED

The Morrison Formation is not mapped separately and therefore is described below.

The most complete sections of the Morrison are in east-central and southern outcrop areas. Mainly grayish-green, tuffaceous siltstone with interbedded sandstone, limestone, and some cherty siderite in the eastern part of the Sun River Canyon area (Mudge, 1972). Maroon and tints of pinkish-gray beds common in the upper part. Cherty siderite occurs as lenses in the middle part, limestone occurs as beds or nodules in the lower part. The Morrison is about 61 m thick in the Sun River area (Mudge, 1972), about 82 m thick in the Wolf Creek area (Schmidt, 1972a). Mostly eroded prior to deposition of the Mount Pablo Formation north of the Sun River area. In most places, the Morrison is less than 30 m thick.

Je ELLIS GROUP (UPPER AND MIDDLE JURASSIC)

Divided into three formations by Cobban (1945), in descending order.

Swift, Rierdon, and Sawtooth. In the Wolf Creek area the Rierdon Formation is absent, the combined thickness of the Swift and Sawtooth Formations is about 65 m. The three formations have an aggregate thickness of about 87 m in the Sun River area, about 205 m thick west of that area, and more than 188 m in the northern part of mapped area (Mudge and Earhart, 1978).

The Upper and Middle Jurassic Swift Formation was divided into upper and lower unnamed members by Cobban (1945). Ranges from 30 to 36 m thick in the southeast to more than 60 m in the northwest. In the northeast, part of the upper member was eroded prior to sedimentation of the Cretaceous Mount Pablo Formation. The upper member is thin-bedded, gray to gray-brown, very fine to fine-grained sandstone. As much as 30 m thick in the Sun River area (Mudge, 1972), less than 3 m thick in the northeast outcrop. The lower member is dark-gray shale with some interbeds of sandstone. A thin bed of poorly indurated glauconitic sandstone with water-worn belemnites and locally chert pebbles, at base of the member except in the northern outcrops. The lower member averages about 15 m thick in the south and about 21 m thick in the north. The Swift unconformably overlies the Rierdon Formation.

The Middle Jurassic Rierdon Formation contains calcareous gray-brown siltstone and claystone in the upper part and calcareous, dark-gray, laminated shale and claystone in the lower part. Many thin beds of argillaceous limestone scattered throughout formation. Barite nodules, numerous pelecypods and some ammonites common. Phosphatic nodules common in the lower part of the northern exposures. About 44 m thick in the Sun River area, as much as 56 m thick to the north.

The Middle Jurassic Sawtooth Formation is divided into three unnamed members by Cobban (1945), the lower member is absent in the northern outcrop area. Ranges in thickness

from 15 to 69 m, thickening to the north. The upper siltstone member is a prominent unit, many thin beds of grayish-brown to yellowish-gray siltstone with a few thin beds of shale, increasingly sandy northward. Lenses of phosphatic pellets common in the western and northern outcrops. Pelecypods common and ammonites rare. Member 6-13 m thick in the south (Mudge, 1972), thickens northward to about 18 m (Imlay, 1962). The shale member is dark-gray shale with some siltstone, sandstone, and a few beds of limestone. Thickens northward from 5 m in the Sun River area to about 77 m near Mount Patrick Gass. Some beds locally pyritic. North of the Teton River contains black, phosphatic pellets and lies unconformably on Mississippian carbonate rocks. The lower sandstone member in the southern part of the area rests unconformably on Mississippian rocks. In most places, hard, fine-grained, and light-gray sandstone beds, conglomeratic in the basal part. Locally consists of two beds of sandstone separated by dark-gray shale. The conglomerate consists of pebbles and cobbles and locally boulders of Mississippian carbonate and chert (Mudge, 1972). The sandstone member ranges from 0-6 m thick, in most places 0.6-2 thick (Mudge, 1972).

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MADISON GROUP (UPPER AND LOWER MISSISSIPPIAN)

Divided into the Castle Reef Dolomite and the underlying Allan Mountain Limestone (Mudge, Sando, and Dutro, 1962), equivalent in age to the Mission Canyon and Lodgepole Limestones in Central Montana. The Madison ranges from about 275 m to 550 m thick, much of the variation in thickness is a result of pre-Jurassic erosion (Mudge, 1972).

The Upper and Lower Mississippian Castle Reef Dolomite, ranges from about 230 m thick in the eastern outcrops to about 305 m in the west, is divided into an upper member, the Sun River Member, and a lower unnamed member (Mudge, Sando, and Dutro, 1962). The Sun River Member, 76-137 m thick, consists mostly of thick beds of fine to medium-crystalline dolomite (Mudge, 1972), and is main hydrocarbon reservoir rock on the Sweetgrass Arch (Chamberlain, 1955). In many places oil residues common in cavities, pores, fractures, and on bedding planes in the upper part of the member. The lower member of the Castle Reef consists of thin to thickbeds of fine to coarsely crystalline, light-gray dolomite, calcitic dolomite, and dolomitic limestone, dolomite content increases westward. Beds of coarsely crystalline encrinites at various horizons in the Castle Reef, increasingly abundant to the north and west. Lenses and nodules of dark-gray chert common in lower and middle parts, light-gray chert nodules common in upper part. In places, sand-filled joints and bedding planes in upper part (Mudge, 1972). Corals and brachiopods common in the formation.

The Lower Mississippian Allan Mountain Limestone, ranges from about 165 to 200 m thick, contains three widespread unnamed members. The upper member is mainly gray, medium-to thick-bedded, fossiliferous limestone with some beds of dolomitic and magnesium limestone (Mudge, Sando, and Dutro, 1962). In places encrinite beds occur in middle and upper parts of member. Member ranges from 42 to 106 m thick. The middle member contains abundant, irregular-shaped lenses and nodules of very dark chert in sparsely fossiliferous, medium-bedded, dark-gray limestone and dolomitic limestone, ranges from 45 to 58 m thick. Chert is dispersed throughout member at 15-25 cm intervals. The lower member consists of very thinly bedded, dark-gray, argillaceous limestone and dolomitic limestone with dark-gray shale partings (Mudge, Sando, and Dutro, 1962). The lower part of lower member contains alternating beds of dark-gray to gray-brown limestone and very calcareous shale, locally potential hydrocarbon source rocks (Mudge, Rice, Earhart, and Claypool, 1978); ranges from 50 m to 67 m thick.